

FLUID BEARING SLIDE ASSEMBLY FOR WORKPIECE POLISHING

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CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation in part of U.S. Ser. No. 10/614,311 filed July 7, 2003 (NT-251C1), which is a continuation of U.S. Ser. No. 10/126,464 filed April 18, 2002 (NT-251) now Pat. No. 6,589,105, and U.S. Ser. No. 10/126,469 filed April 18, 2002 (NT-253), all incorporated herein by reference.

[0002] This application claims priority to U.S. Prov. No. 60/400,542, filed August 2, 2002 (NT-275P), incorporated herein by reference.

FIELD

[0003] The present invention relates to a fluid bearing slide assembly for workpiece polishing. The exemplary embodiments relate to the manufacture of semiconductor wafers, and more particularly to a system and method for a polishing member transport in a chemical mechanical polishing apparatus.

BACKGROUND

[0004] U.S. Patent No. 6,103,628, assigned to the assignee of the present invention, describes a reverse linear chemical mechanical polisher, also referred to as bi-directional linear chemical mechanical polisher that operates to use a bi-directional linear motion to perform chemical mechanical polishing. In use, a rotating wafer carrier within a polishing region holds the wafer being polished. U.S. Patent No. 6,103,628 is incorporated herein by reference.

[0005] U.S. Patent Nos. 6,464,571 and 6,468,139, assigned to the assignee of the present invention and related to the '628 patent, describe various features of a reverse linear chemical mechanical polisher, including incrementally moving the polishing pad that is disposed between supply and receive spools. U.S. Patent Nos. 6,464,571 and 6,468,139 are incorporated herein by reference.

[0006] While the mechanisms shown and described in these patents typically use roller bearings for supporting the polishing pad, roller bearings may have certain characteristics that affect polishing action, for example, in a reciprocating polishing apparatus, rotational momentum must be reversed whenever the belt direction is reversed. The act of overcoming roller bearing momentum

may cause temporary or permanent belt stretching or other unwanted distortion, which can affect the polishing action. Additionally, while the inventions described in the patents are advantageous, further novel refinements are described herein which provide for a more efficient drive system for reverse linear, e.g. bi-directional linear, motion.

SUMMARY

[0007] The invention is a fluid bearing assembly for supporting a polishing member while polishing a workpiece. The polishing member may be, for example, a polishing pad, a polishing belt, or another type of polishing member. The fluid bearing assembly of the invention overcomes potential disadvantages of the conventional ball bearing rollers in which the polishing member mechanically contacts the roller surface.

[0008] An exemplary apparatus for polishing a workpiece comprises a polishing member configured to polish the workpiece. A support structure is coupled to the polishing member and configured to move the polishing member to polish the workpiece. The support structure includes at least one curved fluid bearing coupled to the polishing member and configured to support the polishing member while it is moved to polish the workpiece.

[0009] In one aspect of the invention, the fluid bearing supports the polishing member over a region where the polishing pad plane of travel changes from a first plane to a second plane.

[0010] In another one aspect of the invention, the apparatus further comprising a pressure regulator configured to control pressure of a fluid exhausted from the fluid bearing.

[0011] In another one aspect of the invention, the apparatus further comprising a temperature regulator configured to control temperature of a fluid exhausted from the fluid bearing.

[0012] In another one aspect of the invention, the support structure includes at least two curved fluid bearings coupled to the polishing member and configured to support the polishing member while it is moved to polish the workpiece.

[0013] In another one aspect of the invention, the fluid bearing is a substantially hollow structure with a curved portion constructed from perforated sheet metal.

[0014] In another one aspect of the invention, the support structure includes a supply spool configured to supply the polishing member and a receive spool configured to receive the polishing member; and a slide member coupled to the supply spool and the receive spool and configured to move the polishing pad in a bi-linear manner.

[0015] The invention offers many advantages, including the ability to efficiently produce reverse linear motion for a chemical mechanical polishing apparatus. Another advantage of the invention is to provide for the ability to efficiently produce bi-directional linear motion in a chemical mechanical polishing apparatus that also allows for the incremental movement of the polishing member. Yet another advantage is that angular momentum on the prior art rollers and polishing member is reduced. These advantages create smooth belt motion in all desired directions of movement.

BRIEF DESCRIPTION OF THE DRAWINGS

- [0016] The invention is described with reference to the following figures wherein:
- [0017] Figure 1 illustrates a processing area for polishing a workpiece;
- [0018] Figures 2A-B illustrate a polishing apparatus using a rotating platen assembly according to an embodiment of the invention;
- [0019] Figures 2C-D illustrate a polishing apparatus using linear polishing according to an embodiment of the invention;
- [0020] Figure 3 is a flow diagram of an embodiment of a method of polishing a workpiece;
- [0021] Figure 4 illustrates a polishing member drive system that is preferably used to cause bi-linear reciprocating movement of the portion of the polishing member within the processing area;
- [0022] Figure 5 depicts a flow diagram of an embodiment of a method of polishing a workpiece with a polishing member using bi-directional linear movement;
- [0023] Figure 6A illustrates an example in which a polisher uses a loop-shaped polishing member which is linearly moved by a moving mechanism;
- [0024] Figure 6B illustrates the loop-shaped polishing member of Figure 6A elevated by fluid pressure from a fluid bearing;
- [0025] Figures 7A and 7B illustrate a fluid bearing depicted in side view and cross-section, respectively;
- [0026] Figure 7C depicts another aspect of a fluid bearing, shown in cross-section; and
- [0027] Figure 8 depicts an embodiment of a system for regulating the pressure and/or the temperature of fluid sent to the fluid bearings.

DETAILED DESCRIPTION

[0028] U.S. Patent Nos. 6,103,628 and 6,589,105, which are hereby expressly incorporated by reference, describe a reverse linear polisher for use in polishing a workpiece (e.g. a semiconductor wafer). The embodiments described herein are for purposes of satisfying the best mode of the invention and may be modified while remaining within the scope of the claims.

[0029] Figure 1 illustrates a processing area 20 as described referenced patents. A polishing member 30 is moved in the processing area to polish the workpiece. In the exemplary embodiment, the polishing member is a pad that is moved in a reverse linear manner (i.e. bi-directionally) for polishing the front surface 12 of a wafer 10 within the processing area 20. The polishing member may be, for example, a polishing pad, a polishing belt, or another type of polishing member. The polishing member is driven by a drive mechanism (not shown). The wafer 10 is held in place by a wafer carrier 40 which can also rotate during a polishing operation as described herein.

[0030] Below the polishing member 30 is a platen support 50. During operation, due to a combination of tensioning of the polishing member 30 and the emission of a fluid, such as air, water, or a combination of different fluids from openings 54 disposed in the top surface 52 of the platen support 50, the bi-linearly moving portion of the polishing member 30 is supported above the platen support 50 in the processing area, such that a frontside 32 of the polishing member 30 contacts the front surface 12 of the wafer 10, and a backside 34 of the polishing member 30 levitates over the top surface 52 of the platen support 50.

[0031] While the portion of the polishing member 30 within the processing area moves in a bi-linear manner, the two ends of the polishing member 30 are preferably connected to supply and receive spools 102 and 104 illustrated in Figure 2, allowing for incremental portions of the polishing member 30 to be placed into and then taken out of the processing area, as described in U.S. Patent No. 6,589,105 and below.

[0032] Further, during operation, various polishing agents without abrasive particles or slurries with abrasive particles can be introduced, depending upon the type of polishing member 30 and the desired type of polishing, using nozzles 80. For example, the polishing member 30 can contain abrasives embedded in the frontside 32, and can also be used with polishing agents if desired. Or a polishing member 30 can be used that does not contain such embedded abrasives but instead uses a slurry. Alternatively, some other combination of polishing member, slurry and/or polishing agents can be used. The polishing agent or slurry may include a chemical that oxidizes the material that is subsequently mechanically removed from the wafer. A polishing agent or slurry that contains colloidal silica, fumed silica, alumina particles etc., is generally used with an abrasive or

non-abrasive polishing member. As a result, high profiles on the wafer surface are removed until an extremely flat surface is achieved.

[0033] While the polishing member can have differences in terms of whether or not it contains abrasives, any polishing member 30 according to the invention should be sufficiently flexible and light so that a variable fluid flow from the openings on the platen support can affect the polishing profile at various locations on the wafer. Further, it is preferable that the polishing member be made from a single body material, which may or may not have abrasives impregnated therein. In this context, a single body material means a single layer of material, or, if more than one layer is used, flexibility is maintained by use of a thin polymeric material as described herein.

[0034] An example of a polishing member that contains these characteristics is the fixed abrasive pad MWR66 marketed by 3M company. The MWR66 is 6.7 mils (0.0067 inches) thick and has a density of 1.18 g/cm^3 . As stated above, polishing members are preferably made of a flexible material, such as a polymer. Additionally, the polishing members preferably have a thickness in the range of 4-15 mils. Given such polishing member properties, variation of the pressure of the fluid that is exhausted from the openings on the platen support by less than 1 psi can significantly affect the degree of polishing that occurs on the front face of the wafer, as explained further hereinafter.

[0035] The manner in which the polishing member is used, i.e. whether the movement of the polishing member is linear, bi-linear, or non-constant, may affect the type of polishing members that can be used. However, use of polishing members other than the preferred types of polishing members described above with reference to Figure 1 may result in less effective polishing. Polymeric pads having a low density, such as a density of less than 0.5 g/cm^2 , may be acceptable due to the flexibility inherent to polymeric pads.

[0036] Another consideration with respect to the polishing member is its width relative to the diameter of the wafer being polished. The width of the polishing member may substantially correspond to the width of the wafer, or be greater or less than the width of the wafer.

[0037] The polishing member 30 may be substantially optically transparent at some wavelength, so that a continuous polishing member, without any cutout windows, can allow for detection of the removal of a material layer (endpoint detection) from the front surface 12 of the wafer 10. Additionally, a feedback loop may be implemented based upon signals related to endpoint detection to ensure uniform polishing of the wafer and/or polishing of all of the various regions of the wafer to the desired extent.

[0038] The platen support 50 may be made of a hard and machineable material, such as titanium, stainless steel or hard polymeric material. The machineable material allows formation of the openings 54, as well as channels that allow the fluid to be transmitted through the platen support to the openings. The polishing member levitates above the platen support due to the fluid that is exhausted from the openings. The exhausted fluid may be any fluid medium, such as air, water or some other fluid. By levitating the polishing member, the exhausted fluid causes the polishing member to press against the wafer surface during chemical mechanical polishing. The temperature and/or pressure of the fluid that is exhausted from the openings 54 may be controlled for optimum polishing conditions.

[0039] Figure 2A illustrates a polishing apparatus 200 that uses a rotating platen assembly. The assembly includes a platen 50 held by a support structure 51. A polishing member 30 is extended between a supply spool 102 and a receiving spool 104. In the polishing apparatus, the polishing member is held motionless on the platen by applying vacuum suction through the platen. During the polishing process, the assembly is rotated against a surface of a wafer to be polished. A pair of fluid bearings 112A and 112B is placed at both ends of the platen, facing opposing directions. From the supply spool, the polishing member passes over a first fluid bearing 112A, the platen, a second fluid bearing 112B and the receiving spool. In this embodiment, fluid pressure is applied through the fluid bearings when the polishing member is advanced to bring a fresh polishing member section over the processing area. Figure 2B shows the polishing member elevated by the fluid bearing 112B in the vicinity of the receiving spool. The bearing 112A operates in the same manner, in the vicinity of the supply spool. In operation, after each use of the portion of the polishing member in the processing area, the fluid bearings are activated, the vacuum suction is released, and the polishing member is advanced to the receiving spool. After the advancement of the polishing member, the fluid flow through the fluid bearings is stopped and the polishing member is tensioned on the platen. During the polishing process, a vacuum suction may also be applied through the fluid bearings to further secure the polishing member in place.

[0040] In one aspect of the invention, the fluid bearings use a fluid cushion created by exhausting a fluid (e.g., air, water, or other gases or liquids or gels) from holes in the surface of the fluid bearings. As opposed to conventional barrel rollers that employ an internal bearing over a fixed axle, the fluid bearing design allows for reduced resistance and/or friction against the movement of the polishing member.

[0041] Figures 2C-D illustrate a polishing apparatus using linear polishing according to an embodiment of the invention. These embodiments are more fully described in U.S. Pat. Nos. 6,103,628, 6,468,139, and 6,464,571, incorporated herein by reference. In the present invention, the bearings 112A and 112B are fluid bearings as described above with reference to Figures 2A-B.

[0042] Figure 3 is a flow diagram of an embodiment of a method of polishing a workpiece, for example, using the polishing apparatus 200. In step 310, a polishing member is supported on a fluid bearing between a first end of the polishing member and a second end of the polishing member. The fluid bearing includes a curved portion at which plane of travel of the polishing member changes from a first plane to a second plane. For example, the travel of the polishing member may change from moving in a horizontal plane to moving in a vertical plane, or vice versa, at the curved portion of the fluid bearing. In step 320, the polishing member is moved to polish the workpiece. The moving step may include the step of bi-directionally moving the polishing member. Finally, in step 330, the polishing member is advanced to provide a fresh polishing member.

[0043] A polishing member drive system 100 that is preferably used to cause bi-linear reciprocating movement of a portion of the polishing member within the processing area will now be described.

[0044] Figure 4 illustrates a path 101 that the polishing member 30 travels within the polishing member drive system 100 between the supply spool 102 and the receive spool 104. As shown in Figure 4, the path 101 includes passing from the supply spool 102 over an alignment roller 106A through a top 108A and a bottom 108B right fluid bearing of a slide member 110, and then over each of fluid bearings 112A-112D in a rectangularly shaped path and then around each of a bottom 108C and a top 108D left fluid bearings of the slide member 110, then over an alignment roller 106B and finally to the receive spool 104. Bi-linear movement of the slide member 110 along the horizontal plane 114 will cause the polishing member 30 to move in bi-linear fashion. Thus, the portion of the polishing member 30 disposed within a processing area of the chemical mechanical polishing apparatus can polish a top front surface of a wafer using the bi-directional linear movement of the portion of the polishing member 30.

[0045] As previously mentioned, the bi-linearly moving portion of the polishing member 30 is supported above the platen support 50 in the processing area, such that a frontside 32 of the polishing member 30 contacts the front surface 12 of the wafer 10, and the backside 34 of the polishing member 30 levitates over the top surface 52 of the platen support 50. The movement

mechanism of the polishing member 30 and the details of the drive system are described in U.S. Pat. No. 6,589,105 and U.S. Prov. No. 60/400,542, incorporated herein by reference.

[0046] Figure 5 is a flow diagram of an embodiment of a method of polishing a workpiece with a polishing member using bi-directional linear movement, for example, using the polishing member drive system 100. In step 510, a length of polishing member is supplied from a supply structure coupled to a slide member. In step 520, a length of polishing member is received in a receive member coupled to the slide member. In step 530, the polishing member is supported on a fluid bearing between the supply structure and the receive structure. The fluid bearing includes a curved portion at which plane of travel of the polishing member changes from a first plane to a second plane. In step 540, the slide member is moved bi-directionally to create a bi-directional movement of the polishing member within a polishing area to polish the workpiece. Finally, in step 550, the polishing member is advanced to provide a fresh section of the polishing member within the polishing area.

[0047] In another embodiment, the fluid bearings may be used in various types of polishing apparatuses that use a static polishing member or linearly moving polishing member. Figure 6A illustrates an example in which a polisher 600 uses a loop-shaped polishing member 645 that is linearly moved by a moving mechanism 615. The moving mechanism may have a drive belt 630 with a tractional surface 632 which grips the backside of the polishing member 645. In one aspect of the invention, the drive belt 630 moves linearly around movement rollers 620, thereby causing the polishing member to move linearly. The polishing member passes over a platen 50 and a surface 612 of fluid bearings 610. Fluid bearings 610 have a semi-circular shape. A wafer placed across the platen 50 can be polished by the linearly moving polishing member. Figure 6B shows the polishing member 645 elevated by the fluid pressure from a fluid bearing 610. When the polishing member is moved by the moving mechanism, the fluid bearings are activated to elevate the polishing member above the fluid bearing.

[0048] Referring to Figures 7A-B, a fluid bearing, such as one of fluid bearings 108A-108D or 112A-112D, is depicted in side view and cross-section, respectively. In one aspect, the fluid bearings may be machined from a metal block as a single piece or as a combination of more than one piece. In another aspect, the fluid bearing may be constructed as a substantially hollow structure from stainless steel, titanium, structural plastic(s), composite(s) or another material. The fluid bearing may have a bearing surface 122 which mates with a fluid housing 124. In one aspect, the bearing surface is precision machined. The fluid housing may feature a fluid supply passage 126

located at both sides of the fluid housing. The fluid supply passage supplies the fluid bearing with pressurized fluid. Alternate configurations of the fluid supply passage are also contemplated. The pressurized fluid introduced by the fluid supply passage leaves the fluid bearing through a plurality of fluid holes 127 formed in the bearing surface. The fluid bearings may also include a pair of anchoring rods 128. The anchoring rods allow for internal mounting of the fluid bearing within a polishing member assembly that uses conventional rollers.

[0049] In the aspect shown in Figure 7B, the fluid housing has an elongated L-shape. The bearing surface is a curved rectangular plate enclosing the fluid housing. The bearing surface is preferably configured to have a perfect quadrant shape to allow the polishing member to smoothly bend 90° in its vicinity. A fluid supply unit provides fluid pressure that is delivered to the fluid bearing by a fluid line (an approximate fluid pressure range 50 – 70 psi). The fluid is exhausted from the fluid holes, thereby creating the fluid bearing cushion.

[0050] Figure 7C depicts another aspect of a fluid bearing 750, shown in cross-section. In the aspect depicted in Figure 7C, the fluid bearing is constructed using a one piece bearing surface 122 and a one piece fluid housing 124, creating a substantially hollow structure. As shown, the bearing surface is folded over the fluid housing. Fluid holes 127 allow fluid to be exhausted through the bearing surface by perforating the front surface. By constructing the fluid bearing with the two piece folded construction depicted in Figure 7C, friction against the polishing member can be further reduced because the polishing member only contacts the bearing surface, which is one piece and does not have any seams or roughness that might exist at the joining with another piece. Additionally, the fluid bearing construction depicted in Figure 7C allows the fluid bearing to be constructed using inexpensive fabrication techniques and inexpensive materials, such as sheet metal or plastic.

[0051] Figure 8 depicts an embodiment of the invention for regulating the pressure and/or the temperature of the fluid delivered to the fluid bearings. In one aspect, the pressure and/or temperature of the fluid supplied to the fluid bearings are individually regulated for each fluid bearing. The exemplary system depicted in Figure 8 has two fluid bearings, though systems having any number of fluid bearings are contemplated. A fluid supply 810 is coupled to the fluid bearings 815 and 820 via a main fluid line 845. The main fluid line splits into two lines; a first fluid line 847 which leads to a first fluid bearing 815, and a second fluid line 849 which leads to a second fluid bearing 820. The fluid pressure supplied to the first fluid bearing 815 is individually controlled by a pressure regulator 817. The fluid temperature supplied to the first fluid bearing 815 is individually

controlled by a temperature regulator 819. Additionally, with respect to the second fluid bearing 820, the supplied fluid pressure is regulated by a second pressure regulator 827 and the fluid temperature is regulated by a second temperature regulator 829. In another aspect of the invention, the temperature and/or pressure of the fluid supplied to all of the fluid bearings in the system is regulated collectively.

[0052] Advantages of the invention include reduced handling of the polishing member, which can extend the useful life of the polishing member and reduce defects introduced by fluctuations from surfaces rubbing against one another. The use of fluid bearings also reduces rolling resistance and angular momentum on the polishing member, as compared to conventional rollers. Further, the fluid bearing design may allow for better tension control of the polishing member than with conventional rollers.

[0053] Having disclosed exemplary embodiments and the best mode, modifications and variations may be made to the disclosed embodiments while remaining within the subject and spirit of the invention as defined by the following claims.